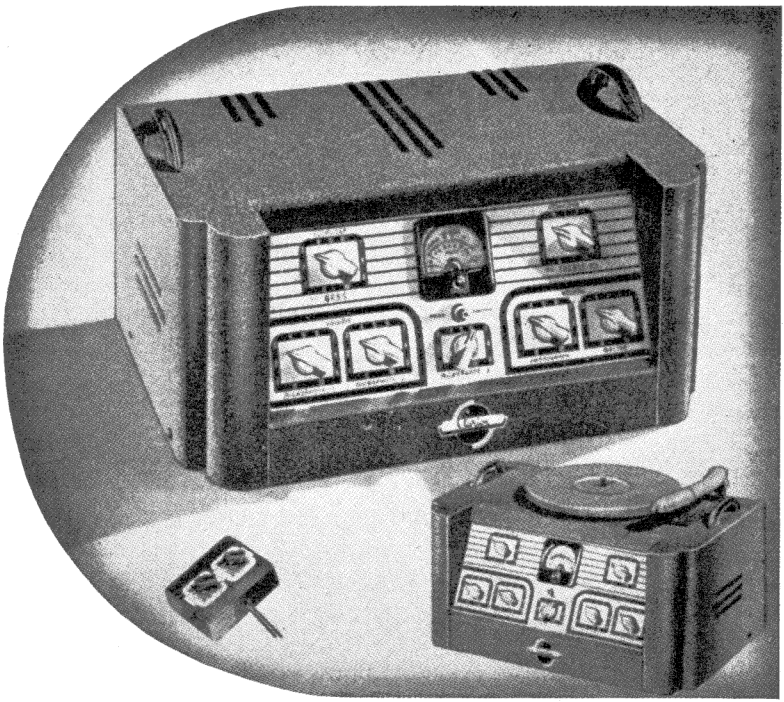
# Public Address or AF Sound Systems

LESSON ND-31

SPRAYBERRY ACADEMY of RADIO

ESTABLISHED 1932

PUEBLO, COLORADO



**The above view shows two types of a Commercial Amplifier. It is available with and without the turn table and pick-up arm. The small unit to the left is a remote volume or gain control. A meter is included, which permits reading the gain in decibel steps.** Courtesy Clarion Sound Systems.

# PUBLIC ADDRESS OR AF SOUND SYSTEMS

LESSON ND-31

This lesson deals with audio amplifiers and their associated equipment. This equipment is employed in broadcast stations, night clubs, schools, churches, etc. In general, the same type of input equipment, power supply systems, reproducers, etc., are used in all of these applications. Some of the subjects you will need to be familiar with in this work are mixing of various types of inputs—this includes microphones of all types, phonograph pick-up units and radio receiver detector outputs—multiple and single speaker installations, connection of transmission lines, etc. All of these things must be handled properly while maintaining the best possible fidelity of reproduction.

The public address amplifier, while usually operated locally—that is, not from a transmission line—should be provided with an input transmission line for special cases. Although indefinitely diversified, the basic input requirements for a public address system are shown in Fig. 1.

Transformer T1 will handle any double button carbon microphone. A battery supply, potentiometer, by-pass condenser and milliameter for microphone current are shown in the circuit. The primary of T1

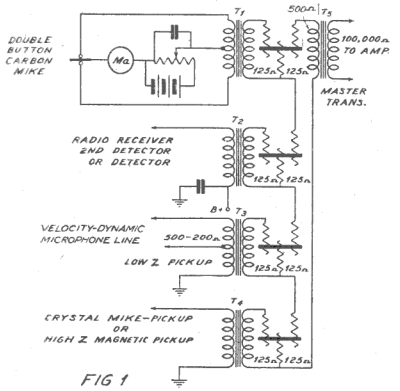



FIG 1

matches the AC resistance of the microphone while the secondary is a 125 ohm winding so that the other three, T2, T3 and T4 in series, each having 125 ohms impedance, will match the 500 ohm winding of the *input master transformer* T5.

*Transformer T2 couples the signal from a radio receiver to T5.* This AF signal may be taken from the output plate transformer of the receiver, from the second detector of a superheterodyne or from the detector of a tuned radio frequency receiver. The impedance of the primary of T2 must match that of the tube or circuit to which it is coupled.

The third transformer, T3, in Fig. 1, is primarily for the purpose of matching a line for remote pick-up and therefore has connections for 200 and 500 ohm transmission lines. This transformer may also be used for *velocity and moving coil microphones* which have their own output transformers matched to the line. A low impedance pick-up may be used at this point if desired. Other taps may be provided for pick-ups of other impedance values so that this transformer comes into service for any *magnetic type of pick-up.*

Transformer T4 has a high impedance primary winding for connection to a *crystal microphone* or *pick-up* or to a *high impedance magnetic pick-up.* T4 and T3 may be combined but where a number of different pick-up devices are used, it is better to have individual coupling transformers. The actual impedance of this winding of T4 may be from 50,000 to 100,000 ohms, depending, of course, on the equipment to be used with it. The T volume controls in Fig. 1 provide for any amount of output from any or all of the sources without changing the impedance feeding into the master transformer (T5).

There are a few variations of input devices peculiar to public address equipment which should be considered before consideration is given to the amplifier proper. In most small AF amplifying units where portability is important, the elimination of the battery power supply for the carbon microphone is a great advantage although it should be kept in mind that carbon type microphones are not used very much anymore. A double button carbon microphone may be operated from a voltage derived from the high voltage power supply by using the proper divider as in Fig. 2.

The buttons of the microphone are shunted by two 200 ohm resistors in series and the diaphragm is grounded. A low value positive voltage well-filtered and fed through R1 from the B+ connection of the power supply is connected at the junction of the two 200 ohm resistors. Variations in

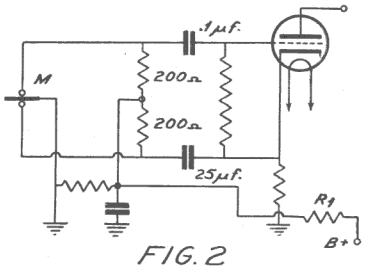


FIG. 2

the division of resistance between the 200 ohm fixed units and the microphone buttons causes a similar variation in voltage distribution across the resistors, and the signal voltages are fed into the input tube of Fig 2. When a filtered DC is used for the double button microphone the 100,000 ohm secondary of the master transformer, T5, of Fig. 1 is switched out of the circuit and Fig. 2 is switched in to take its place in many PA installations.

It may be noticed in Fig. 1 that in spite of the fact that the sum of the impedances feeding into the master transformer of T5 are constant, they are in series and the signal from one source will feed into all of the others if they are the least bit above zero volume adjustment. While it is possible to turn all the other controls to zero when any other source is used, this is often inconvenient and, of course, impossible in cases where it is desired to pick up more than one signal at a time. Distortion will result due to reflection from the *unmatched loads* into which each volume control must feed.

The solution to this problem lies in the use of input tubes for each signal source. The tube is an *unilateral* device; that is, it will act in only one direction. You know, of course, that this is only partially true as at high frequencies there will be feed-back, degeneration, etc., which are reverse acting properties. However, these effects are negligible in the range of AF frequencies and pentode tubes are used so that these effects are further prevented.

A typical arrangement for three input signal sources using this type of *non-reversible* mixer is shown in Fig. 3. It is called an *electronic mixer circuit.* The primaries of T1, T2 and T3 may correspond with any of those in Fig. 1 for picking up signals from any source. Their impedances must, of course, be properly chosen for the purpose. Their secondary impedances are designed to match their shunt *potentiometers* (R1, R2 and R3) and various portions of the signals are selected by the variable arms of the potentiometers for the control grids of the tubes. Obviously, these potentiometers, R1, R2 and R3, have the highest possible practical values (100,000 ohms as a rule) so that the highest possible voltage will be developed across them for the grids of the following tubes.

It must be understood that the transformer secondary impedances can only be approximately matched to the grid input impedance. *The grid input impedance changes with*

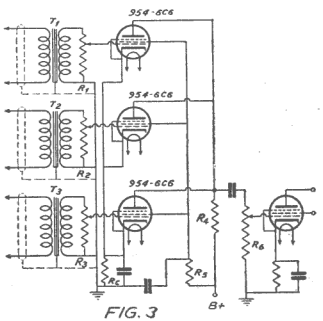


FIG. 3

*frequency, plate load, interelectrode capacity and grid leakage current.* Although normally quite high, its value varies considerably and the best way to match the transformer to the grid input circuit as nearly as possible for all conditions is to use the shunt resistors shown in Fig. 3. The tube's input grid impedance being higher than the shunt resistances usually will make only a small change in the total transformer load. Thus, the lower the potentiometer resistance and transformer impedance, the better the match of the entire circuit *for given changes in the grid impedance.* However, a satisfactory match is still obtained by making these values high for the development of the highest possible value of signal voltage.

The signals are mixed in various proportions in the common plate circuit of the tubes shown in Fig. 3, but these *cannot affect the input* because of the non-reversible nature of the tubes. As you know, the plate to grid capacity is almost eliminated (at AF) and each source is independent of all others. Lately, because of these advantages, the electronic mixer circuit has achieved wide application in practice.

The input signal pick-up devices are usually attached or connected to the mixer circuit by means of a plug and socket. For example, a 3 terminal socket is used for a double button microphone; a 5 terminal socket may be used to admit one or more pick-ups should there develop a need for them. Screw type terminal plugs are also widely used for connecting a microphone or pick-up to an amplifier.

For piezo-electric pick-ups or, in the case where the pick-up impedance is high (2000 ohms and up), the connecting cord or transmission line is shielded and the shield is grounded to the chassis. Whether the first or input tubes are electronic mixers or amplifier input stages, they are usually completely shielded. Moreover, they are placed as far away from transformer and choke coil magnetic fields as possible. The control grid leads are usually shielded completely. All of this extra precaution is taken to prevent the input tubes from picking up stray hum voltages for any signal picked up by the input tubes will be amplified tremendously. This, of course, is just as true for a hum voltage as for a wanted signal—hence the precaution of shielding the input so well.

## THE VOLTAGE AMPLIFIER

The signal fed to the mixer circuit may have a value anywhere from a few microvolts up to 2.5 volts and from this point it must be amplified as nearly as possible without distortion until it is high enough in value to *drive* or swing the grids of the *power amplifier output tubes to maximum.* The value of the required input signal voltage depends on the output amplifier stage or stages, the tubes they use, their class of operation, their efficiency and the final power desired at the speaker input. The input *voltage amplifier* requirements will, therefore, be described first, and, from its characteristics with reference to the output desired, the exact gain and number of stages can be determined.

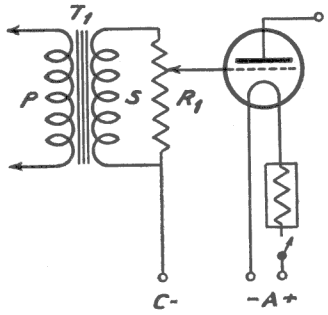



FIG. 5

Just as for receivers, there are public address systems for every type of power supply, and these can be arranged for almost every power output in practical demand. The tubes, therefore, are chosen to fit the type of power supply available. Triodes, tetrodes and pentodes are in common use as voltage amplifiers in all types of public address and AF amplifier systems.

The conventional input stage for an AF amplifier using a triode, tetrode or pentode is shown in Fig. 4. The input tube is symbolized here as a triode. For AC systems this tube may be a 27, 56 or 57 for the 2.5 volt filament class, a 37, 76, 6C5, 6J5, 6P5, 6L5, 6AE5 or 7A4 for the 6.3 volt class. In Fig 5 is shown a typical battery operated input AF tube having a filament as the cathode. For 1.4 volt operation a 1G4 would be used and for 2 volt operation in the medium-mu

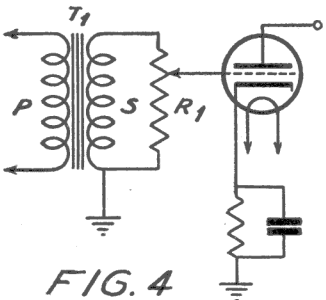



FIG. 4

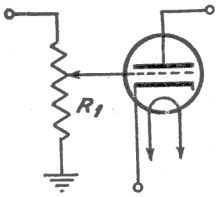



FIG. 6

triode class this tube could be a type 30 tube. Other possible tube types for this type of operation are the 1D8 ,1B5, 1H6, 3A8, 1H5, 1LH4, etc.

R1 in Fig. 5 could be from 100,000 ohms to 500,000 ohms with the secondary of T1 in both cases having an impedance of about 100,000 ohms. If the signal is brought directly from a source of high impedance, Fig. 6 would be used with the same values applying.

An alternative circuit is occasionally used in an input triode circuit which is biased automatically by its cathode voltage drop as in Fig. 7. The *signal voltage drop* across R3 (the bias resistor) is fed into the grid input circuit by way of C1. This circuit is isolated from ground by R2 which is a filter resistor. The signal fed back is practically in phase with the original signal which makes terminal 2 follow the potential of the cathode almost identically. Thus,

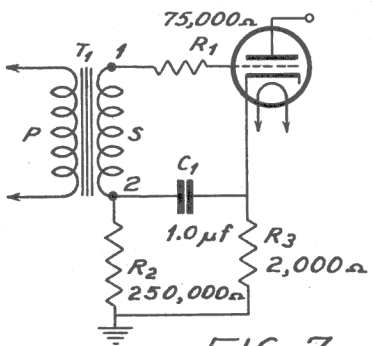



FIG. 7

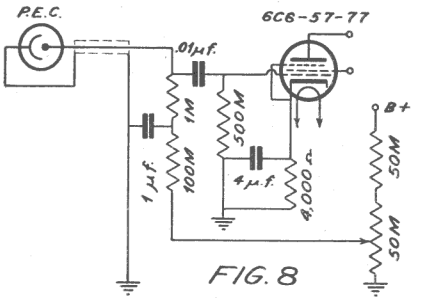


FIG. 8

all of the signal voltage is independent of cathode changes making the true signal substantially equal to that across winding S at terminals 1 and 2. The resistor R1 serves to off-set the effects of possible resonance of S with C1 and also serves to decrease other phase changes in the circuit.

A (PEC) photo-electric cell (for sound picture reproduction) is connected to an AF amplifier input, as in Fig. 8. Transformer coupling of a photo-electric cell to the input is not popular. The photo-electric cell lead should be as short as possible to the first amplifier (6 feet or less) and must be fully shielded. A pentode tube is shown here as this is in keeping with modern practice. A later lesson will describe photo-electric cells in detail.

## TYPES OF COUPLING

At the output of the first *voltage amplifier* in a public address or AF amplifying system there must be some means of transferring the signal to the next stage and, at the same time, this stage must be correctly loaded for most favorable amplification and fidelity.

For the low and medium *mu* triode tubes, transformer coupling or resistance coupling may be used. For all tetrodes and pentodes, however, resistance loading of the plate and capacity coupling to the next stage is practically essential. These high output impedance tubes are primarily voltage operated, constant-current devices. Suitable transformers to match them are not practical.

A typical transformer coupled input circuit using triode tubes is shown in Fig. 9. For a detailed quantitative study of this circuit, assume that tubes V1 and V2 are, in this case, 56 or 6C5 type tubes. It is desired to transfer as much voltage as possible from V1 to V2 *at all AF frequencies*. The impedance of the primary P of T1 must, therefore, be as high as practical. The AC plate resistance of the 56 tube is 9,500 ohms (at a plate voltage of 250) and an impedance of 9,500 ohms for P in Fig. 9 would transfer maximum power to a load or to the secondary. Because of distributed capacity losses, heat and copper losses, a transformer winding cannot very well exceed 100,000 ohms. The secondary impedance then cannot very well exceed this value. Now if S in Fig. 9 is loaded with 100,000 ohms impedance, the primary will show 9,500 ohms impedance if the trans-

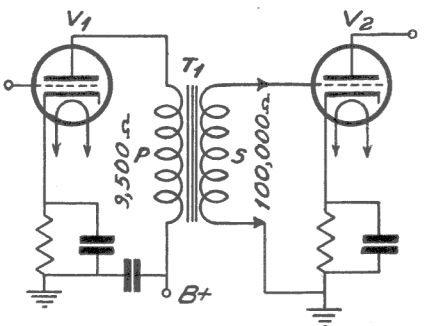


FIG. 9

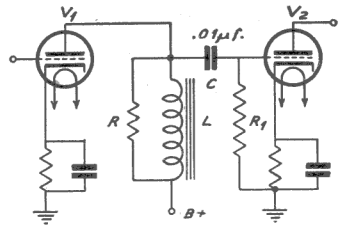



FIG. 10

former winding turn ratio is 1 to 3.24. In a transformer the square root of the impedance ratio is equal to the turns ratio. Thus—

$$\sqrt{\frac{100{,}000}{9{,}500}}=\sqrt{10.52+}=3.24.$$

Since the *mu* of the tube is 13.8, there will be a stage gain of .5 mu when the load equals the AC plate resistance or $.5\times13.8=6.9$. The transformer turns ratio is the same as its voltage ratio; thus $6.9\times3.24$ equals a gain of 22.35. If the primary impedance is increased to take advantage of a higher gain from the tube ,this gain would be lost due to a lower voltage ratio of the transformer *as there is an upper limit placed on both windings of approximately* 100,000 *ohms impedance.*

Next refer to Fig. 10 which is occasionally used as an *interstage* AF coupling system. Although still in use, this circuit is obsolete as it tends to have a *rising amplitude-with-frequency charactertistic.* The choke coil L has the same limitations as a transformer in general and does not have the advantage of voltage step-up.

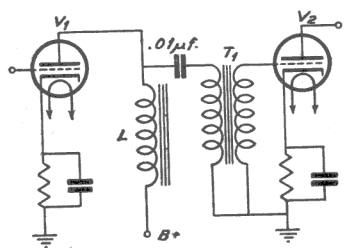



FIG. 11

Certain advantages over the transformer system are obtained by a combination of Figs. 9 and 10, as shown in Fig. 11. Here the DC is not allowed to flow through the transformer primary winding, thus increasing the amplitude range of its signal carrying capacity and decreasing the tendency towards distortion caused by DC saturation of the transformer core.

The most widely used circuit in AF systems is the capacity coupled pentode arrangement, as in Fig. 12. Since the 6C6 tube is very widely used in this type of circuit, the gain of the stage can be determined from conventional values. With the values shown in Fig. 12, and knowing the characteristics of

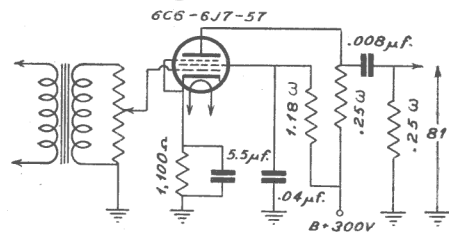



FIG. 12

the tube to be *mu*=1500, the following formula will give the gain:

Rp=1.5 meg.

$$\text{gain}=\text{mu}\,\frac{\text{RL}}{\text{RL}+\text{Rp}}$$

The load RL consists of the .25 megohm plate resistance in parallel with the input grid resistance of the next stage which is also .25 megohm, making a total of .125 megohm. The voltage drop across the coupling condenser (.008 mfd.) averages a value which, when added to the .25 megohm grid input resistor, just about compensates for the shunt effect of

the actual grid-cathode load on the input grid resistance. You may, therefore, consider the total input load to the next stage to be .25 megohm for all practical purposes. Evaluating this, the following is obtained:

$$\text{gain} = 1500 \frac{.125}{1.5+.125}$$

$$= \frac{1500 \times .125}{1.625}$$

$$= 115.38$$

Due to certain losses and other factors such as leakage through shunt capacities for average frequencies, the real gain is usually some 10% less than this in the actual circuit. A conservative figure for this widely used circuit is 100 as the gain. It must be remembered also that this applies only when the input signal is relatively low—around 50 millivolts or lower, down to about 5 microvolts.

Except for the filament supply, these same values may be used for the 6J7 and the 57 tubes. Other RL values, etc., may be used with these tubes for gains anywhere from 50 to 350 per stage. While the very low gains are inefficient and require more stages ,the higher gains should be avoided because of critical operation. It is not best to try to acquire more gain per stage than 100 for this reason in ordinary public address systems. There is a wide variety of tubes which can be used in this connection. For 2 volt operation there are triodes, tetrodes and pentodes, for 5 volt operation there are a few types and for 6.3 volt operation there are several types which, of course, may be AC, DC or battery operated. The tetrode will do almost as good as the pentode as a first stage amplifier when the input signal is low in value. For the second and other following stages, the pentode is by far superior because of the elimination of secondary emission for large signal voltages on the plate. For replacement purposes and for standardization, it is much better to use pentode tubes for all stages where high gain is required.

## THE POWER AMPLIFIER

To determine how many stages must be used and the gain per stage most desirable, it is necessary to carefully consider the *power amplifier* part of the AF system. In this section of public address amplifiers there has been a greater tendency towards diversity than in any other part of such systems. *The same things can be accomplished in a great number of ways,* each of which has its own peculiar advantages.

For a small phonograph record amplifier or for a small inter-office call system where no electrical power source is available, assume that the 2 volt tube with battery operation is preferred. Naturally, for the *voltage* or input amplifier tube you would use a sharp cut-off pentode such as the 1B4 or type 15. For simplicity you will probably prefer a twin triode output tube in place of two separate tubes. A type 19 or 1J6 tube should, therefore, be chosen. This will allow a power ouptut of 2.1 watts which will usually be adequate. If for any reason you must have up to 3.5 watts of output signal energy, the 49 type tube may be used. There are several single tube arrangements to choose from where you require 1

watt or less of output. However, the 19 tube is far more efficient than the other arrangements in the class A application.

An examination of a tube manual will disclose that if the tube is operating constantly, it is better for long life to have the lowest possible plate current flowing while the tube is in operation. This would point to the 1.6 watt operation as being very desirable. Remember this is referring to the low power battery operated amplifier. This operation requires a 6 volt bias which should be applied preferably by a *C* battery. Since grid input power is required (class B operation) you must have a driver tube of the 2 volt type. A 30 or 1H4 type tube will be suitable for this as such tubes are capable of an output power of 260 milliwatts driving power. As a driver, the tube used must be supplied with a plate voltage of at least 157 volts, a bias of −11.3 volts and a plate load of 18,000 ohms. These are manufacturers' specifications based on actual tests. A coupling transformer must be used, and to match the grid input of the 19 or 1J6 tube it must have a *step-down turn ratio.*

The circuit is shown in Fig. 13. The input to the class A driver (30 tube) is a high impedance type and the load in the plate circuit of the tube for driving the 19 tube is 18,000 ohms. The input grid impedance of the 19 tube may be assumed to be 200 ohms (usual value for all class B tubes). A transformer must therefore, have a total grid-to-grid impedance of 800 ohms to feed the grids properly. *Note for transformers the impedance increases as the square of the turns*

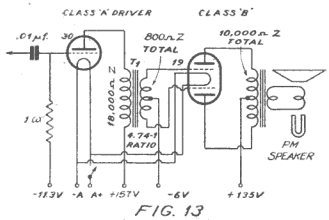


FIG. 13

*increases.* Thus if the number of turns is doubled the impedance will be multiplied by 4. Therefore, 4× 200 or 800 gives the grid-to-grid impedance value of 800 ohms. Thus the transformer ratio is equal to:

$$\text{Ratio} = \sqrt{\frac{Zp}{Zg}}$$

$$= \sqrt{\frac{18{,}000}{800}}$$

$$= \sqrt{22.5}$$

$$= 4.74$$

This is the *step-down* ratio of the coupling transformer T1 in Fig. 13.

Now since the 30 tube is operated as class A, its grid can be supplied with a maximum signal voltage of 11.3×.707 (RMS)=7.92 or practically 8 volts.

Assume now that you are going to use a phonograph pick-up having a level of −35 db. The reference level is 1.73 volts RMS. Given the db level to determine the voltage ratio, the following is obtained:

$$\text{db} = 20 \log \frac{E1}{E2}$$

$$\frac{\text{db}}{20} = \log \frac{E1}{E2}$$

$$\frac{E1}{E2} = \log^{-1} \frac{\text{db}}{20}$$

$$\frac{E1}{E2} = \log^{-1} \frac{35}{20}$$

$$= \log^{-1} 1.75 = 56.25$$

If $\frac{E1}{E2}$ equals 56.25 while E1

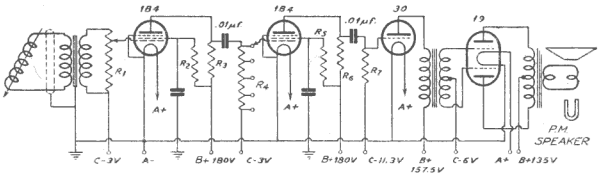



FIG 14

equals 1.73 then $E2 = \frac{E1}{56.25}$

or $\frac{1.73}{56.25} = .0308$ volts.

Raising this to a level of 8 volts for the driver in Fig. 13 will require a voltage gain of 8/.0308= 260 times. You have seen that it is possible to obtain a gain of more than this with a single pentode stage, but this would be unwise as great instability would result. The job of providing voltage gain to drive the power tube may be divided any way as long as the product of the individual gains of two or more stages equals 260 (for the foregoing case). Two stages will be more than enough, making it possible to have a very high grade and stable amplifier. If the gains of the two tubes are to be equal, each must have a gain of the square root of 260 which is approximately 16.1. Here it is obvious that two transformer coupled stages would be suitable as a satisfactory gain of over 20 is easily obtained per stage.

Moreover, you could use one stage with a gain of 10 and one with a gain of 22. The total gain may be divided in any way desired. To take care of the possibility that pick-up equipment of lower input may be used with the system, additional gain (controlled with volume control units) may be used at no additional cost to provide for it. As long as two stages must be used, this procedure is desirable.

In Fig. 14 the complete circuit, capable of handling a much lower input level than −35 db, is shown. Each pentode stage having a gain of 100 makes the gain to the 30 grid 100×100 or 100,000 times, which is 80 db below the 8 volt level, or approximately 66.68 db below the reference signal level of 1.73 volts. It will thus handle any pick-up device rated at −66.68 db or less.

Taps are provided for resistor R4 of Fig. 14 so that any amount of signal may be chosen to be fed to the following grid. If the total resistance is 1 megohm, the signal voltage drop across 2.6% of it will be sufficient for a gain of 260 and for picking up a signal level of −35 db. The lower tap will, therefore, be at the 26,000 ohm point from C negative. Note that 26,000 is 2.6% of 1,000,000 ohms. Often this fixed amplification control is actually calibrated in db units for the input. This does not affect the full volume range available through the use of R1 in Fig. 14.

In this example you have seen that the voltage necessary to drive the grid or grids of the driver or power amplifier must be determined and then suitable stages of amplification must be arranged to supply enough gain to raise the input voltage to the required level. The voltage amplifier may use tubes which are best adapted to the

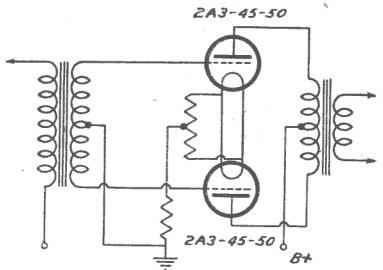



FIG. 15

operating power available. Because of the output ratings, note that if maximum signal is applied to its grid or grids the required power output will be automatically obtained, provided all other parts are of correct value.

The foregoing data has applied to battery operated AF amplifiers in general. However, you should keep in mind that most AF amplifiers are AC operated and that the same design principles apply regardless of the type of power required to operate the amplifier. Many mobile or portable type amplifiers get their basic electric power from storage batteries—a vibrator being used in a manner similar to the system employed in the power unit of an automobile type receiver. Some few amplifiers get their basic power from a small gasoline engine driven generator which may furnish AC or DC depending on design requirements.

Next the output or power stages for different amplifier classes will be considered. Three rather common methods of connecting output triodes for Class A operation are shown in Figs 15, 16 and 17. In Fig. 15 is shown an ordinary self-bias, push-pull class A system. Any low mu power triode tubes such as the 31, 2A3, 45, 50, 6A3, 6B4, etc.,

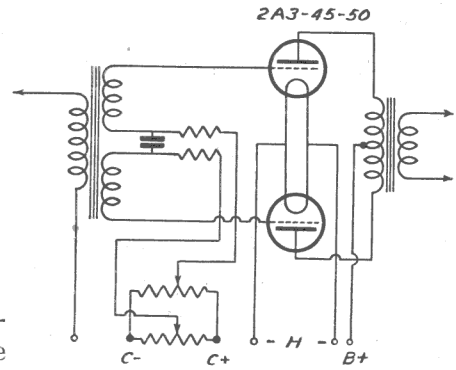



FIG. 16

may be operated in this way provided they are the class A type. In Fig. 16 is shown one way of improving the circuit using *fixed bias* instead of *self-bias*. In ordinary class A operation, it is better to use fixed bias where possible. This makes available more power for the signal instead of it being dissipated by the self-bias resistor and prevents the possibility of degeneration. It being very rare that push-pull or parallel operated tubes will operate in a perfectly balanced fashion, an individual bias is highly desirable—note the variable grid returns in Fig. 16. This permits perfect matching of the tube

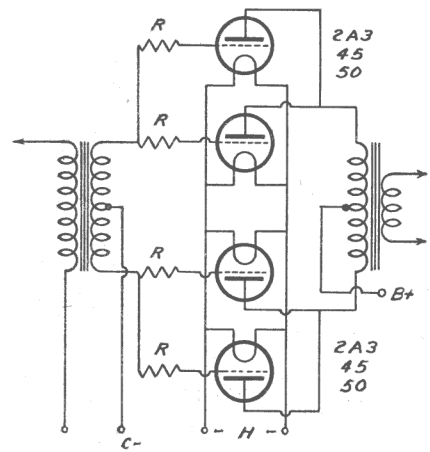



FIG. 17

operation as far as their output is concerned for similar signal voltages.

The operation of two or more tubes in parallel on each side of a push-pull stage allows for greatly increased output without resorting to larger tubes. This is often done as in Fig. 17 for convenience. To prevent one grid in one side of the circuit from affecting the other with changes within the tube during operation, such as gas, etc., both are provided with small resistors (R) called suppressors. Their values are small, from 5 to 100 ohms. This is done almost invariably with parallel push-pull circuits.

Class AB operation, because of its increased efficiency and tolerably low distortion level, has become increasingly popular. For example, it is possible to obtain 18 watts using two type 45 tubes in a class AB circuit. In this operation a bias of 68 volts is used with a plate voltage of 275 volts.

The output tetrode is an efficient method of power amplification, a typical circuit of which is shown in Fig. 18. Such tubes as the 46 and 49 may be used. Of the two individual grids in the tube, the outer one next to the plate is connected to the plate for the driver and both grids are connected together for the power amplifier. As a driver, the tube has ordinary class A characteristics. As a power

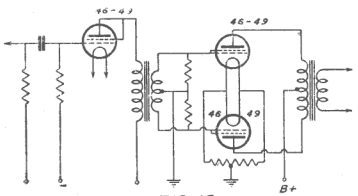


FIG. 18

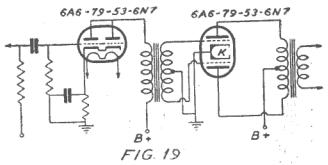


FIG. 19

amplifier, it has class B characteristics requiring no bias.

The proper bias for the driver is −33 volts, indicating that an RMS signal at this grid of 33×.707 or 23.3 volts will produce 20 watts of output energy. The distortion introduced into the signal by a class B amplifier is somewhat more than for class A amplifiers. However, certain methods to be discussed have been used for the reduction of distortion due principally to harmonics generated by the output amplifier.

In addition to the tetrodes for class B there are several twin triodes for class B purposes. The 19 tube covered in Fig. 14 is an example. Other examples are the 6E6, 1G6, 1J6, 53, 6A6, 6N7, 6Y7, 6Z7, etc.

These tubes may be used either as a class A or B amplifier simply by choosing the correct bias. A popular, conventional set-up for these class B twin triodes, as they are called, is shown in Fig. 19. Note that a twin tube is used as a class A amplifier with self-bias while another of the same type serves as the class B output amplifier.

The tubes having the most universal output application are the 59, 89, 1A5, 1C5, 1F4, 1J5, 2A5, 6A4, 6F6, 7B5, 12A5, 25A6, etc. They are termed *triple grid power amplifiers* as they may be used as triodes or pentodes in class A or class B operation. Used as a class

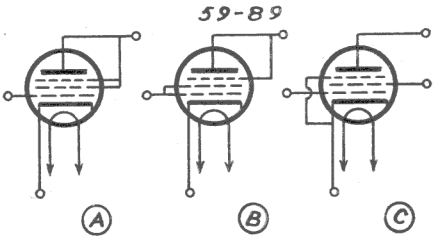



FIG. 20

A driver, the inner grid serves as the control element with the two outer grids connected to the plate at the socket. This is shown in Fig. 20A. As a class B triode output amplifier, the two inner grids are connected together acting simultaneously as control grid, while the outer grid and plates are connected together acting as the anode. Fig. 20B illustrates the connections. A power amplifier circuit using the 59 or 89 would resemble any other equivalent circuit.

The chief advantage of the pentode circuit is that of developing a large output power from a *relatively small input signal voltage.* This is no special benefit in high quality systems as additional gain may easily be added and unnecessary distortion may be eliminated. Inherently the class A triode has the least distortion of the entire group of low mu output tubes. However, where the expense of the installation is already small, and the power requirements are limited, there are advantages in the pentode output. There are probably as many pentode tubes as triodes for power amplification suitable for all classes of operating power.

Outside of the explanation given for push-pull and push-pull parallel operation and the other material covered for multigrid tubes, there are no special circuits for pentodes. Most of them may be used as triodes, but class B operation is to be avoided when the tube is used as a pentode. A typical pentode power amplifier is shown in Fig. 21. At 22 volts on each grid the maximum RMS signal voltage would be 22×.707 or 15.55 volts and this signal would produce around 12 or 13 watts output. Operated as a class AB output amplifier, approximately 19 watts output may be expected with a slightly larger signal voltage.

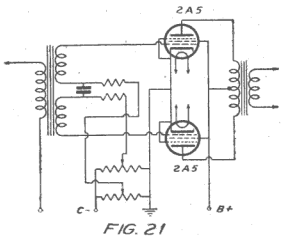



FIG. 21

## THE BEAM POWER AMPLIFIER TUBE

The most recent development in output tubes is the *beam* tube. Its characteristics are basically similar to the pentode, but in place of a suppressor grid this tube uses a deflector type suppressor which *serves to deflect the angle of electron emission.* The grid and screen structures are both close to the cathode with corresponding wires in the same horizontal plane and are oval shaped. The arrangement of the screen wires being *shaded*

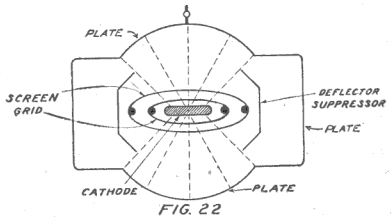



FIG. 22

from the actual electron stream in Fig. 22 means that only relatively few electrons actually strike the screen making the screen current quite low and thereby increasing the efficiency of operation.

A top view of the element arrangement within the beam tube is shown in Fig. 22. The presence of the deflector suppressors as shown, rather than being actually in the electron path, has been found to be a great advantage for efficiency. When the plate voltage drops due to a grid advancing in the positive direction, the velocity of the electrons decrease very rapidly toward the plate, almost stopping near the plate. At this point they accumulate in great numbers, forming a cloud or *space charge,* as it is called, through which *secondary emission* electrons from the plate cannot go. In this way, secondary emission is prevented without using the conventional screen which would cut down the efficiency of the tube. Types of the beam power tubes are the 1Q5, 3Q5, 1T5, 6L6, 6Y6, 6V6, 7A5, 7C5, 25C6, 25L6, 35A5, 35L6 and the 50L6.

It is best to think of a power tube in terms of the power it can deliver at a given grid signal voltage with a definite maximum permissible distortion due to harmonics generated by the tube's operation. The ratio of this power to the grid signal voltage is called the *power sensitivity* of the tube. For a given signal voltage input, the beam type tubes can deliver more power than any other type of tube.

With self-bias, or in single stage circuits, the real advantages of the beam tube cannot be realized while

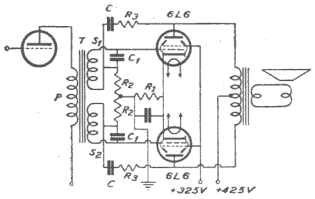


FIG. 23

with fixed bias in a push-pull connection, the harmonic distortion is exceedingly low and the power output very favorably above any other amplifier of equivalent grid and plate ratings. The various circuit uses for such tubes as the beam 6L6 and 25L6 tubes are shown in Figs. 23 through 25.

At Fig. 23, the conventional feed-back circuit is used to reduce the harmonic distortion by feeding back the harmonics in reverse phase so that they are cancelled out. There are three voltage drops from the cathode to each grid in this circuit. One is the DC bias voltage drop across R1 common to both tubes, the next is the harmonic signal voltage drop across R1 common to both tubes, the next is the harmonic signal voltage drop across R2 and the last is the input signal voltage drop across R2 and across the transformer secondaries S1 and S2. The harmonics are conducted through circuit R3-C to the transformer ends of resistors R2. Condensers C1 are filter condensers to level off the amplifying characteristics.

The 25L6, as in Fig. 24, is used exactly as a pentode. This tube is most appropriate for small systems, particularly of the AC-DC type where advantage may be taken of series filament supply.

The operation of the 6L6 in a class AB circuit being driven by a

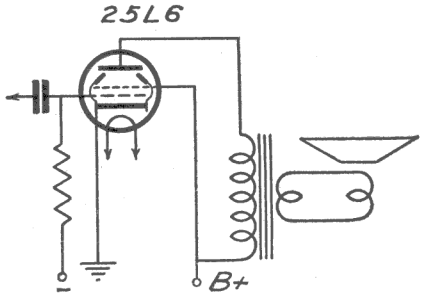



FIG. 24

6F6 power pentode is shown in Fig. 25. This circuit is capable of an output power of 55 watts. This power can be obtained by supplying only 14.1 volts signal to the grid of the 6F6 which, in turn, supplies 850 milliwatts of power to the 6L6 grids. With this power input, the circuit is capable of delivering an output of 55 watts. If you desired to operate a ribbon or moving coil microphone into this circuit (Fig. 25), gain factors would be determined as follows:

From zero db at 1.73 volts to 14.1 volts there is an increase of 14.1/1.73 or 8.15 approximately which is equal to:

db=20 log 8.15
=20×.911
=18.22 db

If the microphone has a level of −65 db, adding the two for a total gain from −65 db to +18.22 db, a value of +83.22 db is obtained. To have this db gain, the actual voltage gain must be—

$$G=\log^{-1}\frac{db}{20}$$

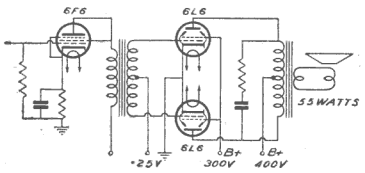



FIG. 25

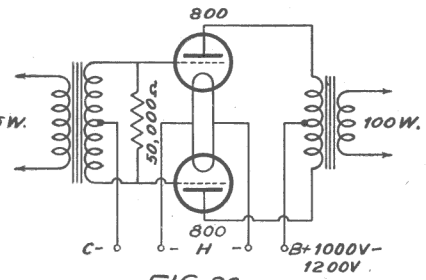



FIG. 26

$$=\log^{-1}\frac{83.22}{20}$$

$=\log^{-1}$ 4.16=14,450 times.

The square root of 14,450 is approximately 120.2 and hence, if you have two stages each with a gain of 120.2 you would have the proper voltage amplifier for this requirement. Two type 6C6 tubes in resistance-capacity coupled circuits would serve the purpose. If you wanted to avoid the possible instability of high gain stages, you could have three equal stages each with a gain of the cube root of 14,450 which is approximately 24.35, or two stages each with a gain of 50 and a third with a gain of 5.78 as the product of 50×50×5.78 is very close to 14,450.

## HIGH POWERED SYSTEMS

The ordinary receiving tube is not always suitable for high powered AF amplification, and, in this case, transmitting amplifying tubes are brought into use because they will develop more power. The 800 and 801 tubes are often used in high powered AF systems. There are, of course, a great number of tubes in the transmitting group extending in their power range from 100 watts up to 20 KW and higher. However, it is quite rare that a public address system will deliver more than 100 watts of AF power.

An output stage employing two type 800 tubes in a class B circuit is shown in Fig. 26. This stage requires 5 watts of input signal from any driver stage which can produce that power and 1000 to 1200 volts on the tube plates. The filaments are heated at 7.5 volts and 3.25 amperes each.

## POWER SUPPLIES FOR AF SYSTEMS

In the low powered AF systems, the power supply does not differ in any major sense from that used in regular receiving circuits. Where there is no electrical power available, other methods must be employed. The usual methods are to employ a generator driven by a gas engine, a wind generator or use batteries. Small, one cylinder gas engines, driving ½ to 1 KW, generators are very widely used in sound trucks and other portable installations. In other cases, for very small jobs the plate voltage may be derived from a vibrator source operating from a 6 or 32 volt battery system. A DC source may be converted into an AC source by means of a motor generator. In still other instances, 110 or 120 volts AC at 25 or 60 cycles is available. It even may be possible to use one or all phases of a 220 to 440 volt 3 phase line as for a transmitter. With a condenser microphone, there is no suitable substitute for batteries. Batteries are still used for carbon microphones and for many types of filament operation, notably with the 2 volt and 6.3 volt series tubes. Batteries also find fairly wide application in bias circuits for high quality work.

AC may be used as a filament supply for voltage amplifiers only if cathode tubes are employed. In some cases, batteries are used for the input voltage amplifier tubes, as it is at this point in the system where the signal is lowest and most susceptible to induction hum. With separate cathode type tubes as voltage amplifiers, operation of the filaments from batteries is rarely necessary in any but the first stage, and even at this point in the system batteries are not used very much any more. Most manufactured AF amplifiers are now completely AC operated.

In the power output stages of an AF amplifier, the filament current is usually quite high so that the emission can be correspondingly high. The filament leads are, therefore, very heavy (large mass) and as short as possible to avoid all possible $I^2R$ loss. The tube or tubes used in the output stage must be as close as possible to the power and filament transformer. When a certain maximum power is reached, it becomes more economical to use a separate filament transformer than simply a filament winding on the power transformer as is done in most receivers. There is another more important reason for this which will be explained shortly.

The plate and screen high voltage supply units have two general divisions applying to the two main types of amplifiers—class A and class B. All voltage amplifier tubes are class A type while the power amplifiers may be class A or class B.

There is one essential difference between a class A amplifier and

other classes such as class AB, A1, B, etc. This is the manner in which the tubes draw current from the power supply. Invariably the class A amplifier draws a *constant current* from the power supply whether or not a signal is being received and regardless of the signal intensity. With this constant drain on the power supply there is no great problem of regulation. The power unit is designed to supply the correct voltages at the proper current flow, and this results in a constant filter action of the filter and a constant power loss for the rectifier and transformer. All of the voltages supplied at the output remain substantially constant; there is no change introduced in the amplifier characteristics with a change in signal strength. This is not true with any other amplifier class, and to make the best possible use of these other amplifiers, new power supply systems had to be devoloped.

As the average signal voltage rises in a class B amplifier, for example, the average plate current of the power amplifier stage also rises. Without any signal, the power tubes are operated very near plate current cut-off. Nevertheless, with resistance coupled stages as voltage amplifiers, the output stages are consuming the most of the output of the power supply. From zero signal to maximum signal, there will commonly be an increase in the current drawn from the power supply of 1000% or 10 times the *no signal* value. Now, if the transformer is a good one, designed to supply the maximum power used to begin with, it will supply this current simply by being loaded more, up to its power limit. But if a high vacuum rectifier tube is used an increased output current will be divided across the rectifier tube and load according to their relative resistance values. Thus, as more and more current is drawn through the rectifier tube, its voltage drop from plate to cathode increases, making the available voltage output drop accordingly. This reduces the voltage applied to all plates and screens in the entire amplifier. While the gain of the voltage amplifier may not be affected very much, the power output of the amplifier will be seriously affected if the voltage reduces appreciably. Not only is the rectifier tube responsible for part of this voltage drop, but the filter is responsible for some of it also. If all of the electrical energy stored in the output filter condenser is used in one or two cycles of the signal and it cannot recharge fast enough to supply successive cycles, the output will be considerably distorted. The high frequencies will still be supplied to some extent as very much less energy is needed for their reproduction. The low frequencies will be lost almost entirely, depending on the values of parts used. Corrections for this difficulty, therefore, include improvements in design of the rectifier and filter with larger power transformer capacity.

It has been found that mercury vapor will ionize at a very low voltage (15 to 20 volts) and will carry an almost unlimited current at this voltage. In fact, the current is only limited by the extent of heat developed in the tube. The hot cathode mercury vapor tube

was the result of this discovery. For some time the mercury arc rectifier has been known as the most efficient high voltage, low or high current rectifier. With no filament, however, the mercury arc rectifier was not practical for low powered use or for portable use. The addition of a filament for *self-starting* and maintenance of the electron flow brought the idea into practical use.

For various power requirements there have been various sizes of these tubes developed as follows:

| Tube | DC Output Current | RMS Plate Volts | Classifications |
|---|---|---|---|
| 1V | 50 ma. | 700 V | Heater-½-wave |
| 82 | 125 ma. | 1,000 V | Fil. full-wave |
| 83 | 250 ma. | 1,000 V | Fil. full-wave |
| 866 | 420 ma. | 5,250 V | Fil. half-wave |
| 866-A | 420 ma. | 7,000 V | Fil. half-wave |
| 872 | 1.73 a. | 5,250 V | Fil. half-wave |

The 82 and 83 tubes are the most widely used for class B circuits up to about 75 watts. Beyond this, the 866 is used while the other larger mercury vapor tubes are used only occasionally in the public address field.

Note that the RMS plate volts are all quite high for these tubes. This is not the voltage impressed from plate to cathode but the voltage that the transformer produces from either end to center-tap. This full voltage, of course, is impressed from plate to cathode during the half cycle in which the plate is negative with respect to the cathode. This voltage must be sufficiently low so that it will not cause an *arc* in the tube which will destroy it. Otherwise, there would be no limit to the voltage applied to the tube. Thus, such tubes are usually rated in terms of their *peak inverse* voltage as this is the limiting factor of their operation.

The voltage drop from plate to cathode in the rectifying direction never exceeds 15 or 20 volts in the mercury vapor tubes and when the current rises to a point where the power lost in heat due to the $I^2R$ loss in the tube exceeds the amount which the tubes can continuously dissipate, the tube will break down. The plate could dissipate, for example, 50 watts, the current could rise to 3 1/3 amperes at 15 volts before any trouble would occur. The plate current values listed for these tubes are for continuous safe operation.

Now when such a power supply is connected to a class B amplifier, as the signal increases, the output stage draws more current, and more current flows through the rectifier tube as its resistance reduces as its current increases, *maintaining a constant voltage drop* across it. More current is instantly supplied by the transformer as with increased load on its windings the primary reactance reduces permitting the primary current to increase. Thus, as far as the transformer and tube are concerned the *output voltage will remain substantially constant for radically changing loads* when a mercury vapor type rectifier tube is used.

The choke coil or speaker fields or both in the power unit have constant resistance, of course, and naturally will drop greater voltage and dissipate more power when greater loads are drawn. This cannot be avoided entirely unless some artificial means is used. However,

the conditions can be helped to a great extent by operating the filter chokes near *magnetic saturation* so that when additional power is drawn they will *swing* into saturation. Thus a type of choke coil called a *swinging choke* is often used in this type of circuit. With a choke coil of large inductance, less current is available at the output or load on the filter than for a choke of small inductance. With the latter, a smaller voltage drop exists across the rectifier so that the filter is permitted to draw 90% or more of the total rectified current. For varying current loads, one choke can serve the purpose of the two functions simply by swinging into saturation with more DC flowing through it. Operated in this way, the inductance may be reduced about 5 times as the load current increases. In this way, the output voltage may be kept fairly constant. From this manner of operation, a choke of this kind is called a *swinging choke* and is recommended for the filter system of a class B amplifier.

All of these details are not evident from a circuit diagram as this will appear just as an ordinary power supply for class A operation. The construction of the choke, however, is different. The air gap used in ordinary chokes is not used in a swinging choke and the *core cross-section* is made small enough so that the proper degree of saturation is reached at the required current flow.

## SPEAKER CONNECTIONS

Consider now the output transformer where it is used to feed the signal to one or more speakers. Provisions are usually made at taps on the output transformer for supplying local speakers, speakers within the general locality of the PA system and remote speakers requiring rather long transmission lines. This strictly local speaker being located not more than a few feet from the amplifier, or built in its cabinet assembly, is supplied directly at its voice coil. Usually impedance taps at 2, 4, 8, 16 and 20 ohms are provided for this purpose so that any one of a great number of speakers of different characteristics may be used with the amplifier. Moreover, groups of speakers may be wired in parallel, series or series-parallel to the output transformer winding.

In this connection, there are three things which must be kept in mind at all times:

1. For any connection whatever, the sum of the individual *power ratings* of all speakers used should equal the power output of the amplifier.
2. The *effective impedance* of any combination of speakers must equal the impedance of the transformer taps to which they are connected.
3. Where possible, each group of speakers connected between two taps on the output transformer should be in parallel.

With these points in mind, consider Fig. 27. Here there is an ordinary voice coil winding of 8 ohms impedance to which is connected two voice coils in parallel. Each has 16 ohms impedance which, in parallel, becomes 8 ohms which is correct for matching pur-

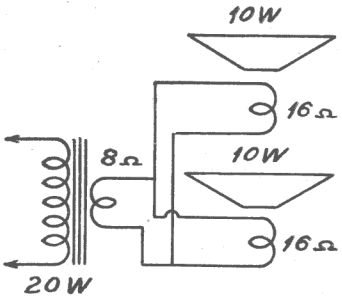



FIG.27

poses. With an output power of 20 watts each speaker can be supplied with 10 watts. Note that this connection checks with the three foregoing requirements. In Fig. 28 there are 4 speakers, each with 8 ohms impedance making a total series-parallel impedance of 8 ohms, but each consumes only ¼ the total power. At 20 watts output, each speaker may take 5 watts, or, if two are 8 watt speakers and two are 2 watt speakers, the entire power output may be utilized for sound reproduction. These are local speaker connections and the connecting leads to the voice coils should be only a few inches from the output transformer. If a foot or more in length, the wire should be quite large because the $I^2R$ loss is very high. If other connections are desired for the speakers, they should be mounted in a *cluster,* and the output transformer should be mounted on their frames. The volume of all speakers in this set-up must be controlled at the main amplifier.

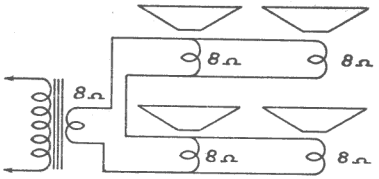



FIG.28

Figure 29 shows a remote speaker set-up where the speakers are perhaps 50 or 75 feet from the amplifier. An individual volume control is used, although these speakers may be controlled at the amplifier if desired. It is, however, very convenient to have a control at the location of the speakers. The 4 ohm secondary of this transformer is loaded by four 16 ohm voice coils and has such a turn ratio that its primary impedance will be 200 ohms. Its ratio will be the square root of its impedance ratio which is equal to:

$$\sqrt{\frac{200}{4}}$$

$$=\sqrt{50}=7.0711 \text{ or } 7.$$

That is, it has 7 times as many turns on its primary (200 ohm) winding as on its secondary (4 ohm) winding. Joining the volume control and amplifier is a 200 ohm line. The amplifier output must have a 200 ohm secondary. As you have learned, it is not essential to use a line with a characteristic impedance of exactly 200 ohms for this relatively short line. It is convenient to use a low impedance line to avoid $I^2R$ loss and sig-

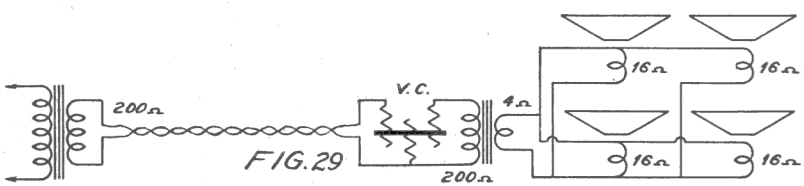



FIG.29

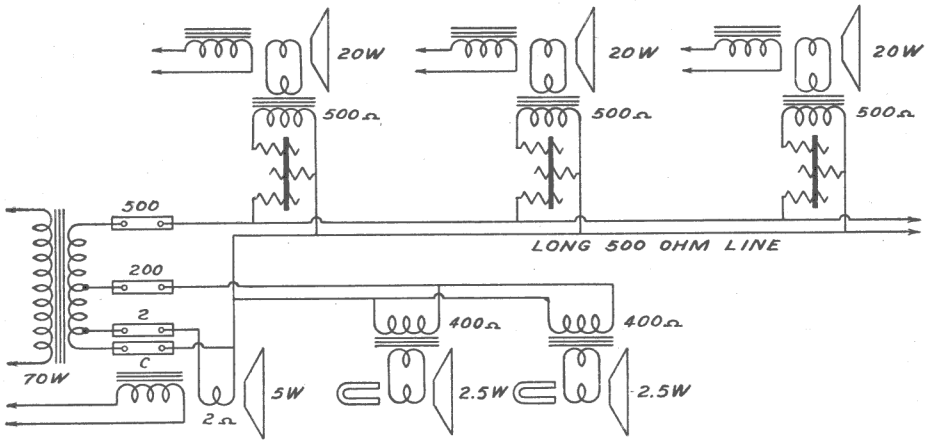



FIG. 30

nal pick-up due to induction, but its exact value is unimportant in this case.

Although unlikely as an actual set-up, Fig. 30 shows a combination of local and remote speakers. The output transformer has a 2 ohm, a 200 ohm and a 500 ohm tap. A 5 watt *monitor speaker* is attached locally and two PM (permanent magnet) speakers are attached to the 200 ohm line not more than 50 feet distant. Note that the primary of each is 400 ohms as their sum must be 200 ohms. To the 500 ohm tap and the common connection C is attached a 500 ohm line. Such a line may extend through a town on overhead poles or around a large park. It may extend around a race track or stadium or anywhere that it may be necessary to address a crowd of people over a wide area.

Each speaker transformer that is attached to the 500 ohm transmission line of Fig. 30 has a 500 ohm primary and a secondary fitting the voice coil of the speaker. The transformers match the line individually in this case, and the line must match the supply transformer impedance. Where the speakers are at a great distance, 300 to 1000 feet from the amplifier, they cannot be considered as a group in parallel as for local or short line speakers.

If two speakers are at one location as some point in a long line, it is best to operate them from one signal transformer having a 500 ohm primary impedance. Where volume control is desired at each remote location, a constant impedance *T* or *H* attenuator should be used, as in Fig. 29.

## SPEAKER FIELD SUPPLY

The DC field supply for all local or monitor speakers for a large system can be derived from the power supply system of the main amplifier or PM speakers may be used which require no field current. Low resistance field windings are placed in series as filter chokes and high resistance fields are placed across the output of the power unit as voltage dividers or *bleeder stabilizers*. For remote speakers, the field coil leads cannot be as long as may be required for

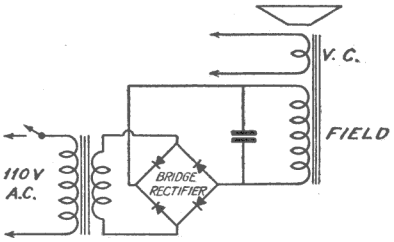



FIG. 31

the speaker, and, hence, the speaker must be supplied with field current independently. Because of this inconvenience of obtaining this independent field supply the permanent magnet dynamic speaker (PM) is coming into use extensively. This, of course, eliminates the necessity of any power supply for the field. For more output and higher power, electro-magnetic fields are still desirable in many installations. Of the two types of supply circuits—the low voltage and the high voltage types—the former has the advantage of using no tubes while the latter has the

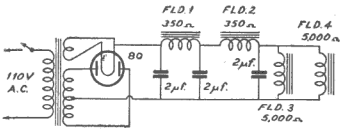



FIG. 32

advantage of supplying many fields simultaneously. The low voltage field supply is shown schematically in Fig. 31. It consists simply of a step-down transformer feeding into a full-wave, copper oxide bridge rectifier which, in turn, supplies high current at low voltage to the field. The *ampere-turns* of the field winding may be the same as for a high voltage field, thus supplying the same amount of magnetism.

Typical high voltage field supplies for one or more field coil windings are shown in Fig. 32. While this circuit shows four fields, it should be obvious that 1, 2, 3, 4 or more field windings may me used as required. The power supply may be designed for any

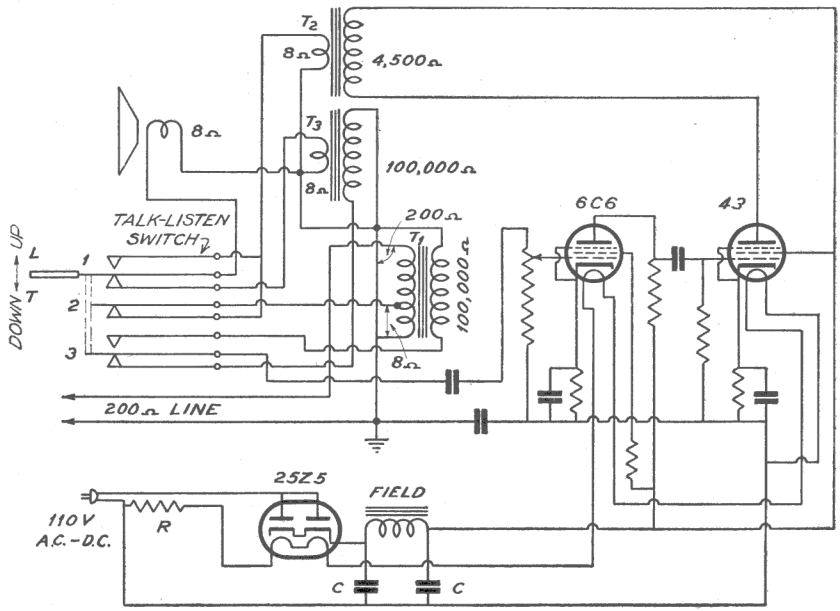



FIG. 33

number of field windings and of those carrying current, one or more may be used without in the least affecting the other fields or speakers. Of course, more than one low voltage field may be wired to the copper oxide rectifier, as in Fig. 31, but usually this type of supply is chosen where only one speaker is used.

## INTER-OFFICE AND CARRIER CALL SYSTEMS

Of special interest in the adaptation of public address systems is the inter-office communication systems, used with wire connections or with power line carrier frequencies. In the wire line connected units, the only new developments have been the *use of the speaker as a microphone* and the switching system.

A very simple self-powered system which will work into a 200 ohm line is shown in Fig. 33. At the left will be seen the speaker, the *send-receive* switch or *talk-listen* switch as it is identified, the 200 ohm transmission line and the 110 volt AC-DC power line cord. The three pole double throw switch remains *up* for the *listen position* so that the signal from the 200 ohm line goes into transformer T1 and from there into the input grid of the amplifier. The output transformer T2 feeds the speaker voice coil with the amplified signal.

In the *talk position*, the switch is pressed down. By talking into the speaker, a signal is generated in the voice coil as it sweeps through the field magnetism. This is directed through another input transformer T3, into the amplifier input. The amplifier output is directed from T2 into the line at the 8 ohm tap on the line transformer T1.

Practically any number of identical units of this kind may be placed across a 200 ohm line connecting any number of offices or rooms for communication to one or all of them. Other systems employ a multi-cable so that any one station may be chosen for communication.

The transmission line may be done away with within one building or in any area supplied with a common AC or DC power line. The building power line may be used as the transmission line. This set-up is somewhat more involved as it includes a *carrier transmitter unit.* The complete circuit is shown in Fig. 34.

When talking into the speaker the signal is fed to the control grid

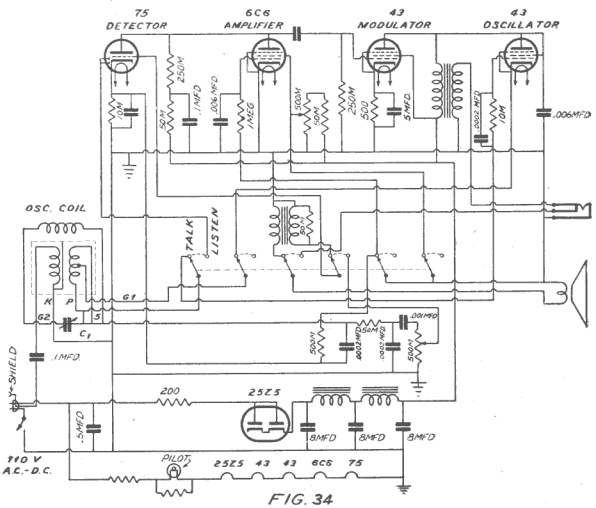


FIG. 34

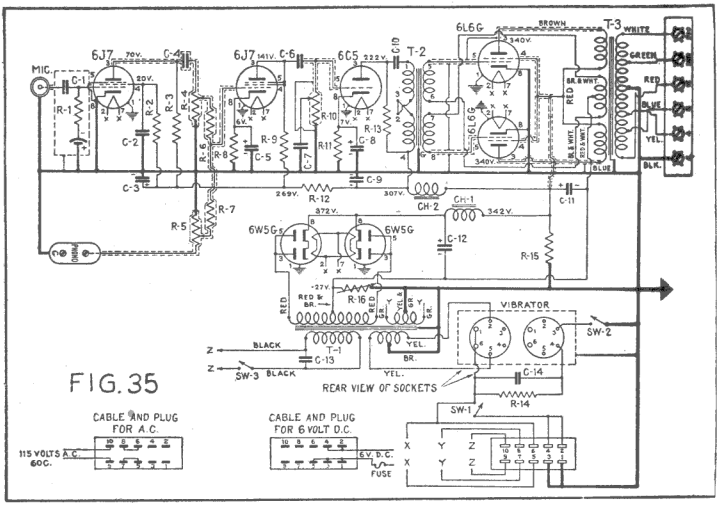



FIG. 35

of the 75 tube and hence to the grid of the 43 modulator tube. This tube plate modulates a 43 oscillator which is feeding the carrier into the line and cable shield. The carrier frequency used is 100 KC in this case.

When receiving, the modulated 100 KC signal enters the tuned oscillator coil from the line and its shield and from there is rectified by the diodes of the 75 tube. The audio signal is then fed to the 75 control grid whence it is amplified and fed to the 43 modulator which now acts as an output amplifier feeding the speaker.

A number of these units may simply be plugged into any AC or DC power line and communication may be immediately established between any two or groups of similar units.

## TYPICAL COMMERCIAL AMPLIFIER CIRCUITS

In this latter section of the lesson is presented nine circuits of amplifier systems as made available by Thoardson Electric Mfg. Co. and the United Transformer Corp. The circuits from Fig. 35 through 40 are made available through Thoardson and those from Fig. 41 through 43 by United Transformer. In some cases parts are available for the construction of these or similar amplifiers. Further information may be obtained by writing to the manufactuers.

In Fig. 35 is shown the circuit of a 25 watt amplifier that may be operated from a 6 volt storage battery or from the usual AC power line. It employs two 6L6 tubes in the output stage in a class AB1 system. It has two input channels —one for a *mike* and the other for a *pick-up* unit. The same power transformer is used for 6 volt vibrator operation and for AC. Note, however, separate primaries are required for the two types of operation.

Figure 36 shows a small 8 watt AC operated amplifier. Input connections are provided for a microphone and pick-up unit. This is a three stage unit with a single 6L6 used as the output tube. The power

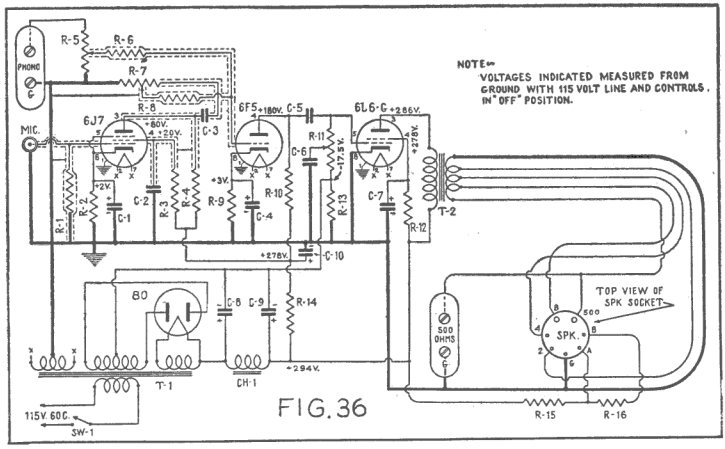



FIG. 36

unit is arranged to supply about 6 watts of field current. The speaker may be the 8 or 10 inch type with a 5000 ohm field. One or more 500 ohm PM speakers may also be used with this amplifier if desired. Transformer T2 provides several output impedance values for matching to almost any type of speaker.

Figure 37 shows a 15 watt amplifier. This is a medium size amplifier and very popular. Two 6L6 tubes are used in the output stage in a class A1 circuit. The input circuit contains a high impedance *mike* and pick-up channel. Independent controls are provided. Thus almost any type of microphone and pick-up unit may be used. Two speaker sockets are provided for voice coil and field connections. Ten watts of field excitation are provided allowing for a 500 ohm field or two 2500 ohm fields. The input connection marked Pol-v is for a polarizing voltage for a condenser type of microphone or for a photo-electric cell (which you will study in a later lesson).

Figure 38 shows a 40 watt amplifier. As in the other amplifiers previously rescribed two 6L6 tubes are used in the output stage. In this connection you will probably

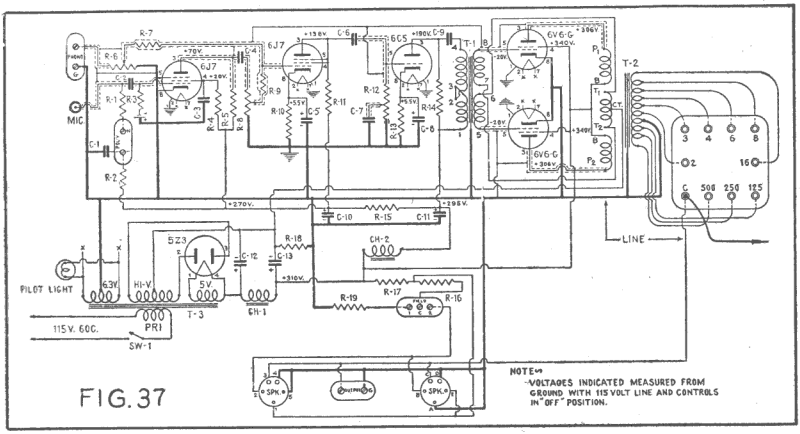



FIG. 37

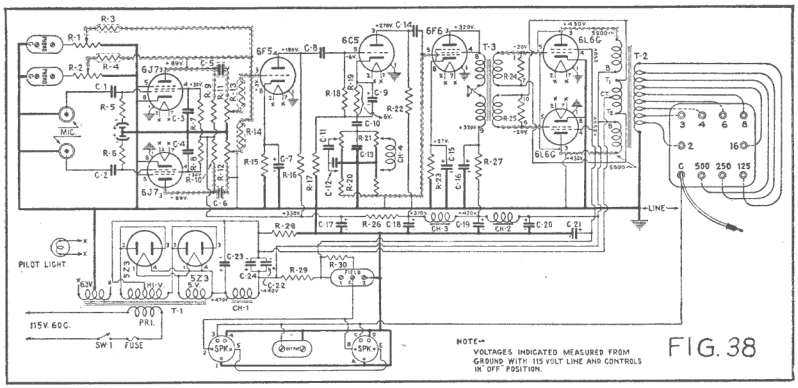



FIG. 38

be interested in the fact that the output power obtained from this type of tube depends on the class of operation and the applied voltage to the plates and screen grids. This circuit uses class AB2 amplification with 400 volts on the plates and 250 volts on the screen grids. In this amplifier two microphones and two pick-up units may be connected to the input. This does not mean that all are used at the same time. For instance, microphones may be at two different locations and continuous music may be had from two pick-up units by proper use of R1 and R2—that is, fading from one to the other. Two 5Z3 rectifier tubes provide sufficient current, —25 watts of this being allowed for the operation of field coil windings (250 volts at 100 milliamperes). This allows for one large auditorium speaker or from two to four smaller speakers. Different speaker voice coil connections are provided for at the output transformer. There are four input channels —two for microphones which may be of the crystal, dynamic or velocity types and two pick-up channels for crystal or magnetic pick-ups.

The amplifier of Fig. 39 is a large 120 watt unit. This amplifier is usually used in connection with a smaller preamplifier which may by located a considerable distance away from the main amplifier. A

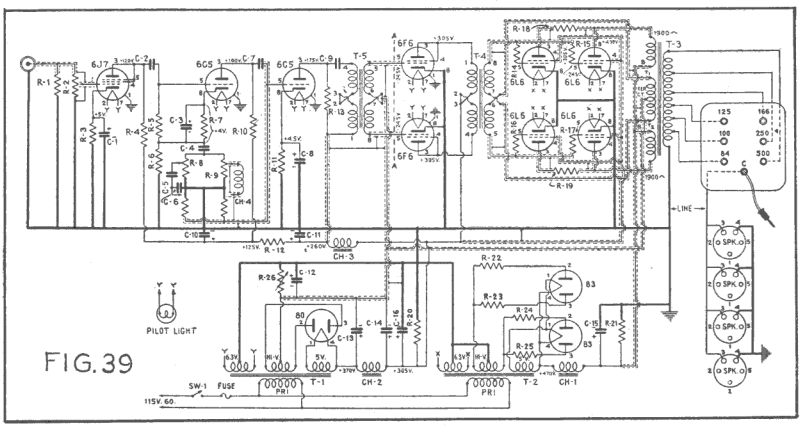
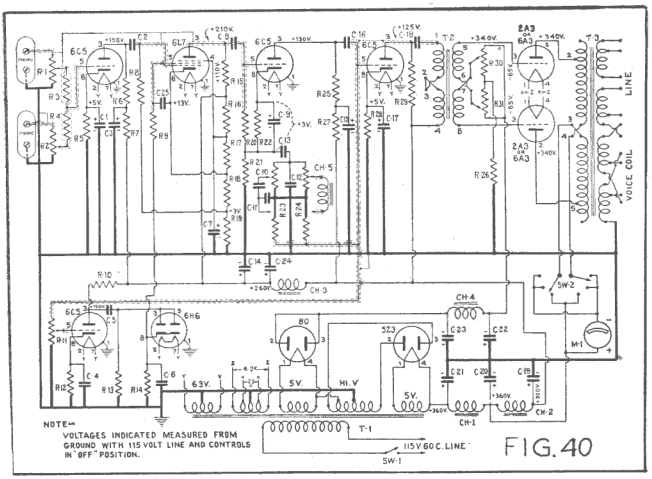



FIG. 39


NOTE—
VOLTAGES INDICATED MEASURED FROM GROUND WITH 115 VOLT LINE AND CONTROLS IN "OFF" POSITION.
115 V. 60 C. LINE
VOICE COIL
LINE
FIG. 40

output stage of this amplifier employs four 6L6 tubes in a push-pull parallel class AB2 circuit. Two 6F6 tubes are used as a push-pull driver stage—the tubes in this case being connected as triodes. Note two power units are used for this amplifier. Two 83 type tubes supply plate current for the output stage with one 80 tube supplying fixed bias and screen grid voltage for the output stage as well as plate voltage for the other tubes in the amplifier. A separate filter system is used for each power supply insuring good regulation. A single input circuit is used for this amplifier although it may be adapted for any type of mixer input by using the proper input transmission line of about 500 ohms *characteristic impedance* is used to connect the two amplifiers. The second tube in Fig. 39 is a special type of tone control circuit. The purpose of this circuit is to boost or attenuate the bass or treble frequencies independently of each other. A later lesson in your SAR course will describe this and other tone control circuits. The

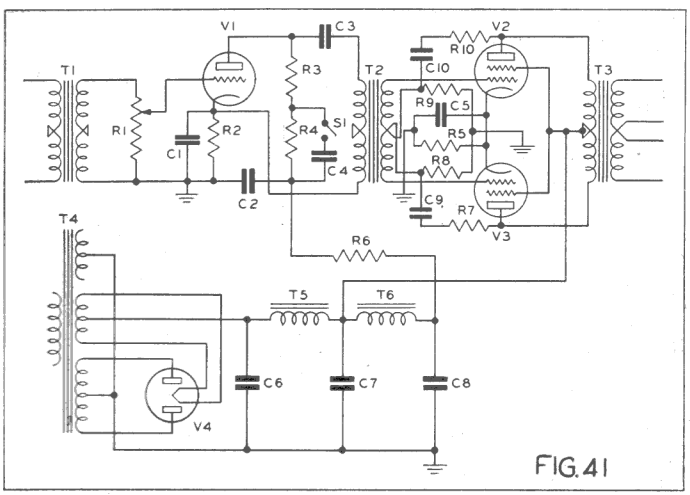


FIG. 41

| COMPONENTS | |
|---|---|
| T1 | LS-10X |
| T2 | LS-19 |
| T3 | LS-57 |
| T4 | LS-70, PA-422 |
| L1 | LS-92, PA-100 |
| L2 | LS-94, PA-45 |
| C1 | 10 Mfd. |
| C2 | .5 Mfd. |
| C3 | .25 Mfd. |
| C4 | .1 Mfd. |
| C5 | 10 Mfd. |
| C6 | 8 Mfd. |
| C7 | 8 Mfd. |
| C8 | 8 Mfd. |
| C9 | .25 Mfd. |
| C10 | .25 Mfd. |
| R1 | .5 Meg. |
| R2 | 3000 ohms |
| R3 | 5000 ohms |
| R4 | .1 Meg. |
| R5 | 175 ohms |
| R6 | 50000 ohms |
| R7 | .1 Meg. |
| R8 | 10000 ohms |
| R9 | 10000 ohms |
| R10 | .1 Meg. |
| S1 | SPST switch |
| V1 | 6C5G |
| V2 | 6L6G |
| V3 | 6L6G |
| V4 | 5Z3 |

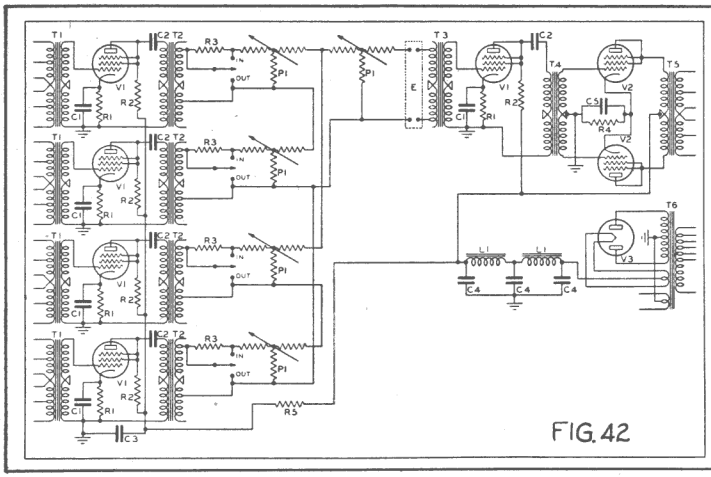


FIG. 42

COMPONENTS

| | |
|---|---|
| T1 | LS-10X |
| T2 | LS-50 |
| T3 | LS-10 |
| T4 | LS-21 |
| T5 | LS-61 |
| T6 | LS-190 |
| L1 | LS-90 |
| C1 | 25 Mfd. |
| C2 | .25 Mfd. |
| C3 | 1 Mfd. |
| C4 | 8 Mfd. |
| C5 | 10 Mfd. |
| P1 | 200 ohm T-pads |
| R1 | 3000 ohms |
| R2 | 25000 ohms |
| R3 | 200 ohms |
| R4 | 500 ohms |
| R5 | 10000 ohms |
| V1 | 6C5, 6J7, 1603 |
| V2 | 89, 42 |
| V3 | 80 |

transformer and padder control units.

The amplifier of Fig. 40 is especially designed for phonograph record reproduction. It is a 10 watt unit giving a high degree of fidelity. Note the input will permit the use of two pick-up units which will allow continuous music because, by means of $R_1$ and $R_2$, fading from one pick-up unit to the other is possible. In all, five stages are used which permits a gain of 70 db from either pick-up unit. In the lower left corner of the diagram a *volume expander* circuit is used. Volume expansion is used in both receivers and amplifiers. You will study this subject in a later lesson. If desired, this amplifier may be arranged to reproduce the output from a detector tube in either a

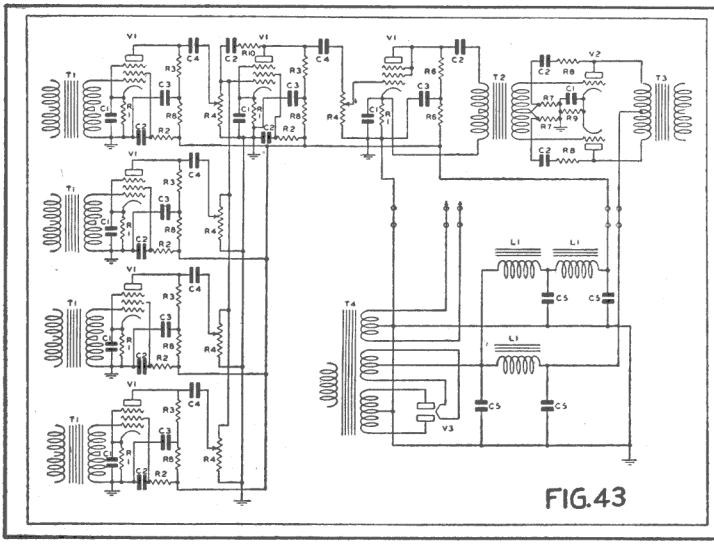


FIG. 43

COMPONENTS

| | |
|---|---|
| T1 | HA-100X |
| T2 | HA-104 |
| T3 | HA-114 |
| T4 | HP-123 |
| LI | HC-117 |
| C1 | 10 Mfd. |
| C2 | .25 Mfd. |
| C3 | 1 Mfd. |
| C4 | .1 Mfd. |
| C5 | 20 Mfd. |
| R1 | 2500 ohms |
| R2 | 2 Meg. |
| R3 | .25 Meg. |
| R4 | .5 Meg. |
| R5 | 2000 |
| R6 | 25000 |
| R7 | 10000 |
| R8 | .1 Meg. |
| R9 | 600 |
| R10 | 1.5 Meg. |
| V1 | 1620 |
| V2 | 6F8G |
| V3 | 6X5, 84 |

TRF or super receiver. In this way, both record reproduction and radio signals may be amplified. All that is necessary to accomplish this is to use a proper input coupling transformer.

Next consider Fig. 41. It was designed for home phonograph record reproduction. The power output is 12 watts and the gain is 50 db. The input is a 6C5 driving a pair of 6L6 tubes in class A operation. The input transformer is for a low impedance pick-up although any other type of pick-up may be used with suitable input transformer. The letters and numbers to the right of the diagram refer to manufacturers' part numbers.

The amplifier circuit of Fig. 42 is called a *console type* pre-program amplifier. Such a unit is used in broadcast stations or in schools or churches where it is necessary to mix signals from several sources. Note the use of an electronic mixer type of circuit. Two 89 or 42 type tubes are used in the output stage and these feed the main amplifier or transmitter by use of transformer T5 and a suitable transmission line. The total gain of this amplifier is 70 db with uniform amplification between 30 and 15,000 cycles.

In Fig. 43 a circuit similar to Fig. 42 is shown. It employs four input mixer tubes in an electronic type of mixer circuit. The output transformer T3 may feed suitable speakers or a transmission line to a transmitter or main amplifier of a PA system. The numbers and letters to the right of the circuit give part values and manufacturers' part numbers.

In your capacity as a radio man, you may be called upon to service, install and sell public address equipment. You may build these yourself or obtain manufactured units from your radio parts jobber. Any parts you need may be ordered through your parts jobber, and it is suggested you consult with him whenever you have an opportunity for a sale. As for servicing and repair of this type of equipment it is essentially the same as for receivers and your SAR service course covers this fully.

# QUESTIONS

**No. 1.** What type of input mixer circuit prevents one input source from feeding a signal into the other input sources?

**No. 2.** What type of coupling is best for high gain pentode voltage amplifiers?

**No. 3.** Is the amplifier stage preceeding a class B power amplifier a voltage amplifier or a power amplifier?

**No. 4.** Why is it not necessary to calculate the voltage gain from the pick-up all the way to the speaker voice coil?

**No. 5.** Is the transformer T1 in Fig. 13 used as a step-down transformer or as a step-up transformer?

**No. 6.** Does a class AB amplifier stage have a higher or lower grid bias than a class A amplifier stage?

**No. 7.** What type of rectifier tubes are most suitable for use with class B amplifiers?

**No. 8.** What relation should the power ratings of several speakers have to the total output of the amplifier, regardless of their connection?

**No. 9.** In Fig. 30, if you turn the volume control of one of the 20 watt speakers off, would this affect the volume or impedance match of the other two 20 watt speakers?

**No. 10.** How is it possible to transmit and receive AF communication signals over a line carrying electric power at 60 cycles?